Assessing the Credit Risk of CDOs Backed by Structured Finance Securities: Rating Analysts' Challenges and Solutions

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This Version: August 31, 2007

ABSTRACT

The CDO market grew strongly in the last several years thanks to a strong U.S. housing market, a low interest rate environment, abundant global excess liquidity, and a healthy U.S. economy. The growth slowed significantly in 2007 amidst an unprecedented housing market turnaround and the sudden performance deterioration of recent-vintage subprime residential mortgages-backed securities (RMBS). CDOs' large exposure to these subprime RMBS brought them under intense scrutiny. The illiquidity, novelty, and complexity of CDOs made them easy targets of criticism. This paper describes the evolution of CDOs backed by structured finance securities (SF CDOs) and the analytical approaches used by Moody's to rate SF CDOs. We show that SF CDOs have experienced substantial changes in the last eight years in terms of asset distribution and transaction structure. We find that this sector has been dominated by Aaa-rated securities (about 85% by dollar volume of issuance), which did not experience any defaults and losses as of the end of 2006. Although recently issued SF CDOs are expected to perform poorly, not all SF CDOs are backed by subprime RMBS and CDO performance is expected to vary significantly across transactions. This paper also describes Moody's methods for the modeling of four basic components – default probability, recovery rate, asset correlation, and prepayment rate – and the differences and similarities across different rating models for transactions with and without complex waterfalls. Additionally, we analyze the rationale of a number of structural features such as par haircuts on lowly rated assets and assets purchased at deep discount in SF CDOs and additional stresses that are designed to protect SF CDO investors. Finally, we note that the changing distribution of CDO assets and the different credit cycles to which these assets have been subjected make it difficult to interpret the average statistics computed for the overall CDO sector during a short data sample period that covers only a part of the credit cycle for each asset type.

1. Introduction

The CDO market has not received as much attention in its more than ten years of history as it has today thanks to an unprecedented turnaround in the U.S. housing market. The intense interest is clearly commensurate with the sheer volume of subprime residential mortgage-backed security (subprime RMBS)[2] issuance and of collateralized debt obligations (structured finance CDOs) that subsequently resecuritize them.

The heavy volume of subprime RMBS issuance is in large part attributable to abundant global excess liquidity, a long period of historically low interest rates, a booming housing market, and a healthy U.S. economy. According to data from JP Morgan, the total amount of subprime RMBS issuance was roughly US$515 billion in 2005 and US$492 billion in 2006, whereas the global CDO issuance (including structured finance CDOs) totaled US$296 billion and US$508 billion, respectively.[3] By way of comparison, total U.S. corporate bond issuance was US$753 billion in 2005 and US$1,059 billion in 2006, which is roughly equivalent to the combined volume of subprime RMBS and global CDOs.[4]

After several years of strong growth, the U.S. housing market slowed down significantly in the third quarter of 2006. Since then, the annual growth rate of national house prices has continued to slide. The slow-down in the U.S. housing market was unprecedented. Historically before 2007, the worst housing market slow-down was observed in the fourth quarter of 1991, according to the housing price index data from the Office of Federal Housing Enterprise Oversight (OFHEO), when the annual national house price appreciation (HPA) rate fell by 5.7% to 0.3% from 6.0% a year prior. As a comparison, the annual national HPA rate was just 4.3% in the first quarter of 2007, down 8.3% from the 12.6% level a year prior (see Figure 1).[5]

The sudden performance deterioration of recently issued subprime mortgages shocked the credit market and drove a set of recently created, but widely observed, subprime RMBS price indices (ABX.HE) down significantly in a few weeks of time during the first half of 2007. For example, the ABX.HE 2006-2 BBB price was about 96 cents on the dollar on January 1, 2007. It dropped to about 72 cents at the end of June and around 41 cents by mid-August. Furthermore, the fear of contagion penetrated the other sectors, widening spreads across virtually the entire credit market.

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[2] Subprime loans are sometimes referred to as "home equity" loans and subprime RMBS is sometimes referred to Home Equity ABS, or simply HEL.

[3] These numbers are compiled from various issues of JP Morgan's Global ABS/CDO Weekly publications in 2006 and 2007.

[4] These data come from the Securities Industries and Financial Market Association at www.sifma.org.

[5] According to the Case-Shiller house price index, the annual national HPA was in fact negative (-1.6%) in the first quarter of 2007 relative to the same quarter in 2006. The OFEHO's house price index is based on transactions involving conforming, conventional mortgages purchased or securitized by Fannie Mae or Freddie Mac, whereas the Case-Shiller house price index is based on both conforming and non-conforming (jumbo) mortgages. In addition, the two indices cover somewhat different geographical areas and use different weighting methods in the index calculations. See Leventis (2007).

The large exposure to subprime RMBS securities brought CDOs under intense scrutiny. Meanwhile, the illiquidity, novelty, and complexity of CDOs made them easy targets of criticism. The excessive use of leverage by some funds and the attempt to mark-to-market these illiquid credit instruments exacerbated the crisis by triggering demand for frequently and accurately priced CDOs.[6]

Figure 1:

Annual House Price Appreciation (HPA) Rates and Moody's Home Equity Index Delinquency Rates
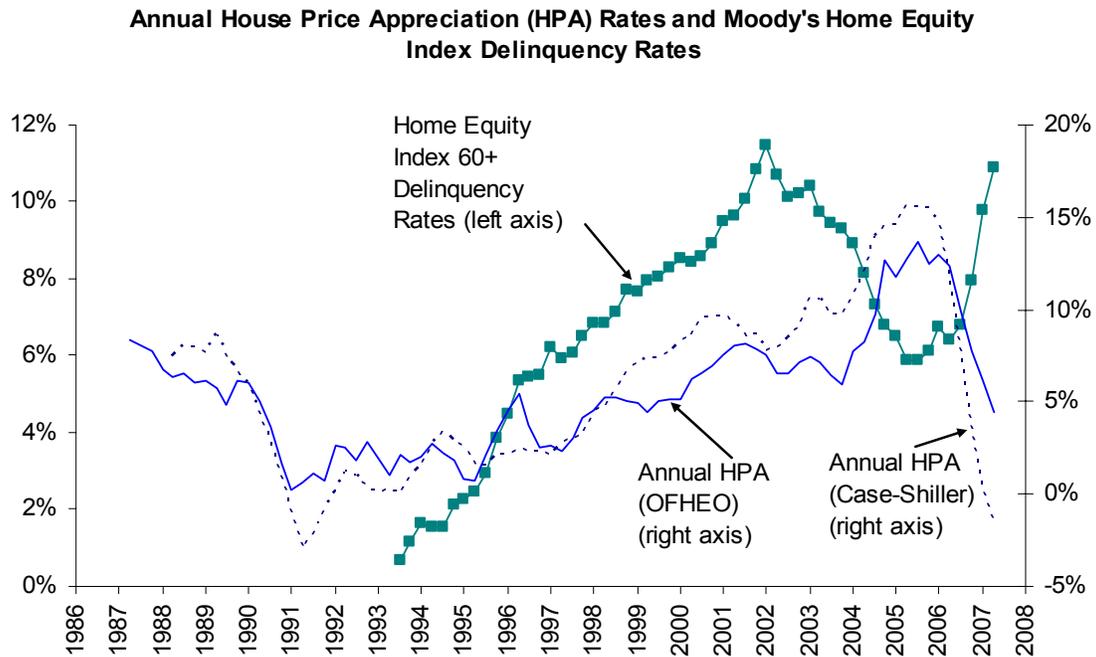
Note: Both OFHEO and Case-Shiller annual national house price appreciation rates are presented for comparison purposes. Home equity index delinquency rates are from Moody's proprietary database.

The objective of this paper is to describe the evolution of the structured finance (SF) CDO sector[7] and to present the analytical approaches Moody's uses to rate these transactions. We show that the sector has constantly been changing since it was first introduced in the late 1990s, and in response, Moody's SF CDO rating methodologies have been regularly updated to keep up with market developments and the most recent research findings.

In the remainder of this paper, we first review the evolution of the SF CDO sector. We will then discuss the meaning of Moody's ratings in CDOs and the rating process. We analyze both the quantitative and qualitative components of Moody's approach to rating

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[6] Duffie (2007) points out that the innovations in credit risk transfer (CRT) security designs including CDOs increase the liquidity of credit markets and offer investors an improved menu and supply of assets and hedging opportunities. However, he argues that even CDO specialists are currently ill equipped to measure the risks and fair valuation of tranches that are sensitive to default correlation. He suggests that this is currently the weakest link in CRT markets, which could suffer a dramatic loss of liquidity in the event of a sudden failure of a large specialty investor or a surprise cluster of corporate defaults.
[7] SF CDOs are also known as ABS CDOs or resecuritizations.

SF CDOs. Next, we illustrate some of the data sampling issues in the study of the credit performance of SF CDOs and report some interesting findings about their historical performance. In the final section, we summarize the key points in the paper and offer a few concluding remarks.

2. Evolution of the SF CDO market

The CDO market developed quickly in the mid- to late-1990s led by high yield collateralized bond obligations (HY CBOs) and high yield collateralized loan obligations (HY CLOs). However, the poor performance of high yield corporate bonds during the 2000-2001 recession negatively affected the performance of HY CBOs and caused total CDO issuance to decline.[8] Meanwhile, the issuance of SF CDOs, which Moody's first rated in 1998, increased sharply from less than US$9 billion in 2000 to about US$20 billion in 2001 (see Figure 3). As a result, the share of total CDO issuance attributable to SF CDOs increased from 10% to 31% over the same time period (see Figure 2). The SF CDO share has remained above 30% ever since. By 2006, SF CDOs accounted for approximately 55% out of a total of US$350 billion in CDO tranches rated by Moody's (excluding non-dollar denominated tranches and wrapped tranches.[9])

Figure 2:
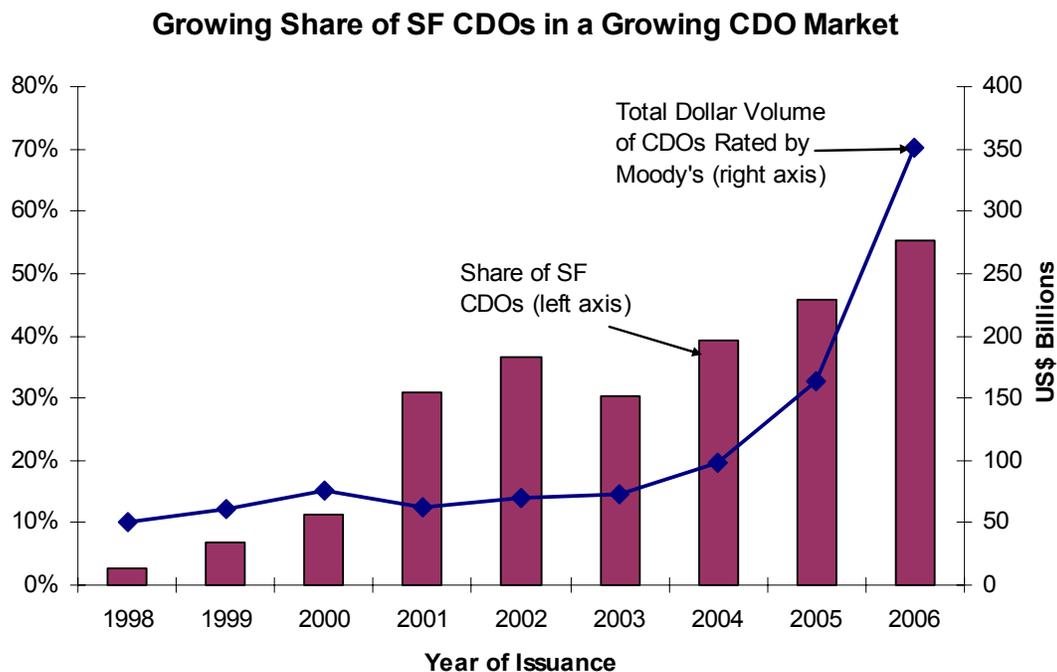
Growing Share of SF CDOs in a Growing CDO Market

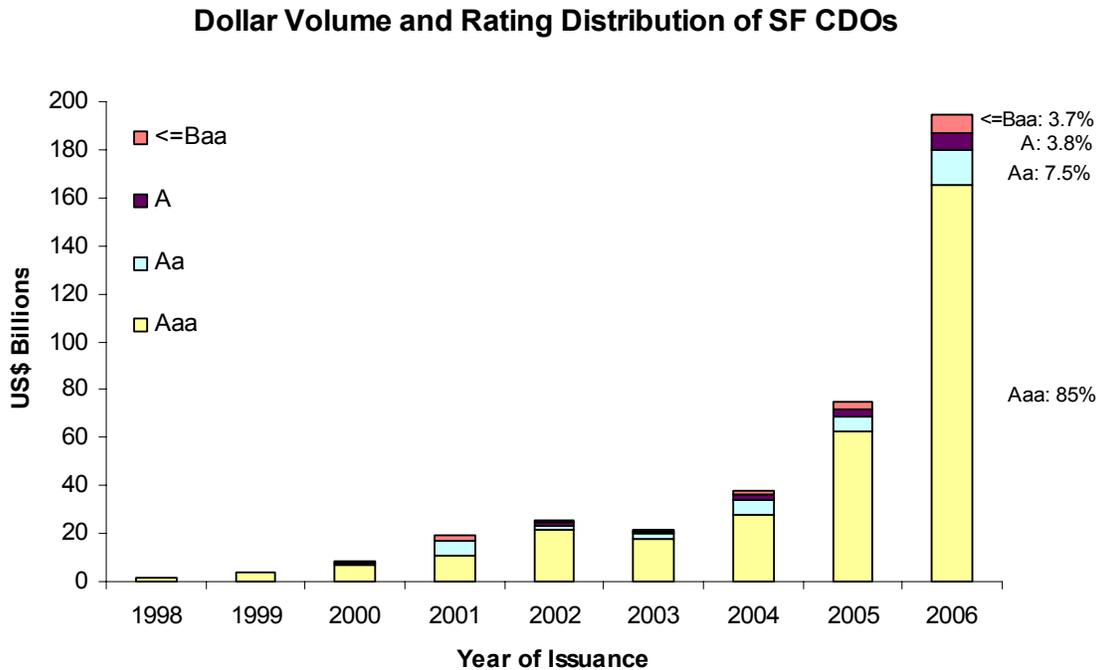Note: The data in this chart does not include non-US$ denominated tranches and wrapped tranches.

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[8] See Moody's Special Comment, "Default & Loss Rates of U.S. CDOs: 1993-2003," May 2004.
[9] The principal and interest payment of wrapped tranches are unconditionally guaranteed by a Aaa-rated financial guarantor. Moody's typically excludes wrapped tranches from its studies of credit performance in structured finance.

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Like the overall structured finance market, the SF CDO sector has been dominated by Aaa-rated tranches, especially when measured by dollar volume of issuance. When measured by number of tranches, the Aaa share is lower but they remain the largest rating category. For example, in 2006, Aaa-rated tranches accounted for approximately 85% of all SF CDOs by dollar volume and 36% by number of tranches. By comparison, tranches rated Baa or below comprised only a small fraction of the total issuance at roughly 3.7% in 2006, although they did account for 24% of all rated tranches in the year.
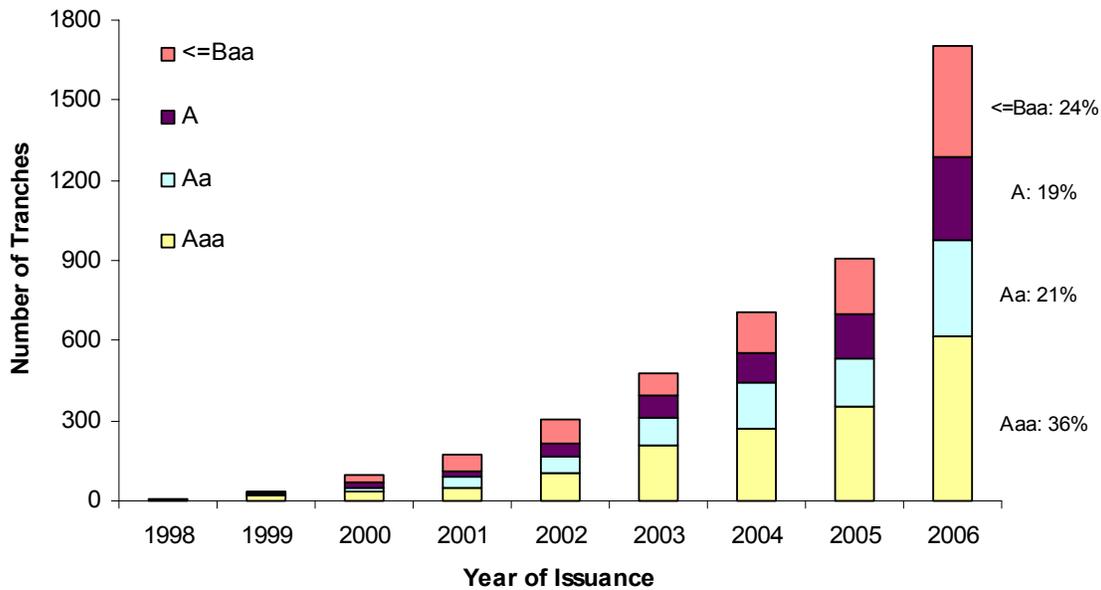
Figure 3 –

Dollar Volume and Rating Distribution of SF CDOs

Note: The data in this chart does not include non-US$ denominated tranches and wrapped tranches. "<=Baa" represents securities rated Baa or below.

Figure 4 -

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Number of Tranches and Rating Distribution of SF CDOs

Note: The data in this chart includes all rated tranches regardless of their currency denomination and excludes wrapped tranches. "<=Baa" represents securities rated Baa or below.

The strong growth of the SF CDO sector has been coupled with significant changes in the distribution of its underlying assets. Most of the SF CDOs issued during 1999-2002 were cash flow transactions backed by diversified pools of instruments such as CMBS, manufactured housing ABS, RMBS, REITs, HY CBOs, and corporate debt (See Figure 5).

In the aftermath of the 2000-2001 economic recession, the poor performance of HY CBOs, manufactured housing ABS, franchise loan ABS, and aircraft lease ABS led to losses in the underlying pools of many early SF CDOs.[10] As a result, the issuance of SF CDOs declined in 2003. The industry realized that diversification just for diversification's sake was not the most prudent collateral management strategy. Meanwhile, asset managers moved away from poorly performing asset types to strongly performing and traditional asset types such as RMBS, with which they were most familiar. As a result, the share of RMBS collateral including those backed by subprime, Alt-A, and prime mortgage loans rose dramatically to about 60% and such instruments have since become the dominant asset type in the SF CDO sector. The growing utilization of subprime residential mortgage-backed securities as collateral reached an all time high in 2005 when they accounted for half of the total collateral par among cash and

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[10] See Moody's Structured Finance Special Report, "Credit Migration of CDO Notes, 1996-2004, for US and European Transactions," March 2005.

hybrid SF CDOs.[11] In 2006, the share of subprime collateral declined to about 40% but the share of all RMBS as a combined category kept rising and surpassed 85%.

Figure 5 -

Distribution of Asset Types Backing Cash and Hybrid SF CDOs
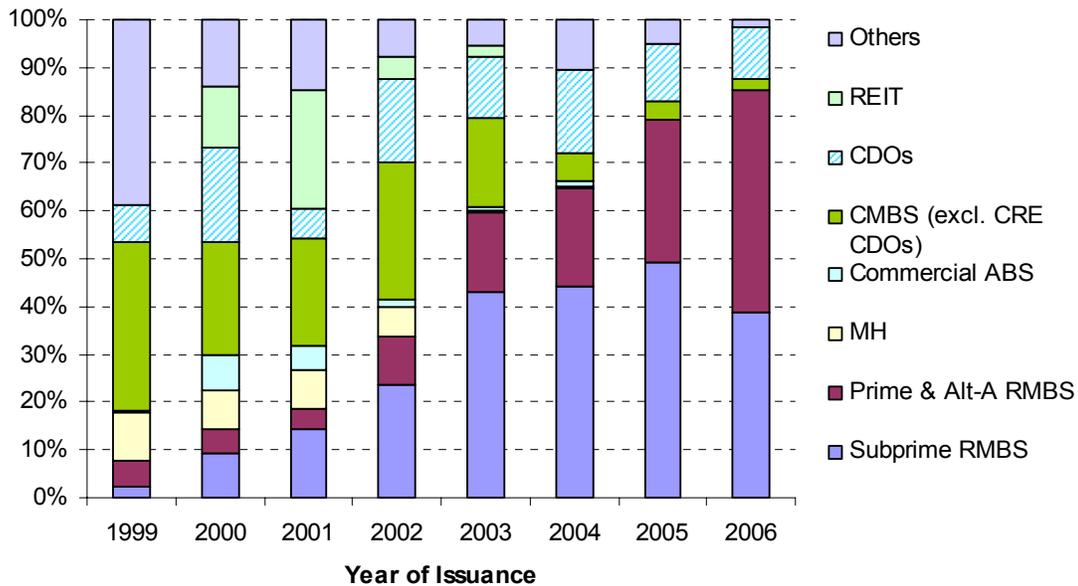
Note: The share by asset type is calculated by summing up the collateral par amount belonging to a given asset type but from all transactions and dividing it by the total collateral par amount of all transactions. CRE CDOs and synthetic SF CDOs are not included in this figure. The share of subprime mortgage related SF CDOs would be higher if synthetic deals were included.

One notable observation in Figure 5 is that in spite of the dramatic increase in the issuance of subprime RMBS-backed CDOs, a substantial portion of SF CDO collateral was not linked to subprime RMBS, but to prime or Alt-A RMBS.

In addition, as SF CDOs invested more heavily in subprime RMBS, highly rated collateral pools became more common. In fact, approximately 40% of the SF CDO transactions (by count) issued during 2003-2006 were high-grade transactions.[12] These high-grade transactions typically purchased collateral rated single-A or higher, with an average rating in the Aa range, as opposed to mezzanine transactions that typically bought Baa or single-A collateral, with an average rating in the Baa range.[13]

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[11] We lack complete asset exposure data for all synthetic SF CDO deals. The reference pool of these deals typically contains a large share of subprime collateral.

[12] For more data and discussions on the collateral distribution of SF CDOs, please see Moody's Special Report, "The Impact of Subprime Residential Mortgage-Backed Securities on Moody's-Rated Structured Finance CDOs: A Preliminary Review," March 23, 2007.

[13] Moody's structured finance credit performance research have shown that highly rated tranches enjoyed higher rating stability and less downgrade and default risk than did lowly rated tranches. For the latest

The share of subprime RMBS securities in the collateral of SF CDOs also varied from transaction to transaction. For instance, while some mezzanine SF CDO pools had more than 80% exposure to subprime RMBS, others contained less than 10% of such exposures.

There are multiple reasons behind the rise of subprime RMBS as a leading collateral type for SF CDOs. The aforementioned collapse in the performance of some early vintage SF CDO assets such as HY CBOs and MH ABS led to a search for new collateral that ended in the subprime mortgage sector. Wide spreads on subprime RMBS securities also made them particularly attractive for arbitrage purposes. As a new kind of asset collateral sourced from the consumer sector, subprime RMBS were also perceived to be able to yield substantial benefit of diversification.[14] Finally, the strong housing market combined with a low interest rate environment provided a fertile ground to produce loan collateral on a massive basis.

Another significant development for SF CDOs was the introduction of credit default swaps (CDS) into the RMBS market. Most SF CDOs prior to 2006 were entirely cash flow structures that had small baskets for CDS that mostly went unused. The few SF CDOs that incorporated synthetic technology tended to use customized CDS documentation to transfer credit risk off of bank balance sheets.

In June 2005, ISDA produced the first version of the "pay-as-you-go (PAUG)" CDS form, which led to a proliferation of CDS on RMBS, which first turned up in fully synthetic SF CDO transactions. By 2006, CDS on RMBS made their way into cash flow transactions as CDS baskets continued to increase. By the end of the year, most mezzanine SF CDOs were of a hybrid form, which incorporated synthetic technology into both the assets and liabilities. The collateral pools were almost entirely synthetic with some baskets for cash assets and the liabilities included both funded and unfunded tranches.

The hybrid transactions provided the utmost flexibility for collateral managers to access exposures that were previously unavailable in a cash only market. Additionally, many hybrid CDOs also allowed managers to take short positions on obligations for hedging or speculative purposes. These innovative transactions also presented many challenges for rating analysts and investors who were trying to understand the more complex structures and documentation. The hybrids incorporated all the risks inherent in cash and synthetic CDOs while creating others specific to these deals. There was very little structural uniformity across deals and arrangers and the CDOs continued to change form throughout 2006.

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reports, see Moody's Special Comments, "Structured Finance Rating Transitions: 1983-2006," February 2007, and "Default & Loss Rates of Structured Finance Securities: 1993-2006," April 2007.

[14] The tradeoff between diversification and specialization is not often well understood. Diversification typically helps if new assets have relatively limited downside and managers' monitoring incentives are strong; when assets have high downside or the effectiveness of monitoring is low in new assets, diversification has little benefit and may actually increase the risk in the pool because most likely the new assets will fall out of a manager's area of expertise. See Winton (1999).

3. Moody's Analytical Approaches to Rating SF CDOs

The Meaning of Moody's CDO Ratings and the Rating Process

Moody's CDO ratings aim at differentiating the expected credit loss of CDO tranches by their final legal maturity. Expected credit loss (EL) is defined as the product of default probability and loss severity given default. This rating approach differs from that of other agencies that primarily differentiate the probability of default.[15] Moody's ratings do not address any potential loss of the market value of CDO tranches, which can be impacted by many risk factors such as illiquidity and interest rate risk in addition to credit risk. Furthermore, expected loss is the first moment of a loss distribution and is only one of the many risk factors that determine the level and change of CDO market spreads.[16]

Upon receiving a transaction proposal from the arranger,[17] Moody's analysts perform both qualitative and quantitative analysis for the proposed transaction. We will discuss the quantitative analysis in detail in the next section. The qualitative rating analysis includes two main components:

First, Moody's reviews all significant legal documents for CDOs. For cash flow and hybrid CDOs, these typically include an indenture, collateral management agreement, and swap documentation. For synthetics and hybrids, the CDS confirms and ISDA Schedules typically also contain key terms. Moody's analysts review the documents to help determine whether the CDO model conforms to the true structure of the transaction as described in the documents, to help flag any significant legal or structural issues, and to help assess the incentives of parties such as the collateral manager.

Second, regardless of whether a transaction allows for trading, Moody's assesses the expertise, judgment and motives of collateral manager – the entity that selects the initial portfolio.[18] Some of the traits Moody's looks for include prior CDO experience, a deep knowledge of the underlying collateral, sufficient staffing, a strong risk management system, the technology infrastructure, and financial resources.[19] In the more typical case of a managed transaction, Moody's evaluates the ability of the collateral manager to trade assets, including identifying troubled collateral as early as possible. Moody's also needs to be comfortable that the manager will adhere to the terms of the collateral management

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[15] Fender and Kiff (2004) provide some detailed discussions on pros and cons of different CDO rating models. We note that Moody's CDO rating models are subject to updates and revisions as new data and research findings become available to us.

[16] For a study on the relationship between credit spread, rating, and credit performance of structured finance securities across different sectors, please see Moody's Special Comment, "The Relationship between Par Coupon Spreads and Credit Ratings in US Structured Finance," December 2005.

[17] Contrary to some misconceptions, Moody's rating analysts are not involved in the structuring and pricing of CDO transactions. In addition, it is natural that rating analysts and arrangers need to have dialogues as arrangers make changes to satisfy investors and present these changes to rating analysts for review.

[18] See "Moody's Approach: Preparing CDO Managers for Moody's Operating Reviews," Moody's *Rating Methodology*, December 2002.

[19] See Moody's Special Report, "Response to Frequently Asked CDO Questions (Second of Series)," July 2001.

agreement and has the expertise to fully understand the legal documents that govern the CDO.[20]

The lead analyst presents the results of both his or her quantitative and qualitative analysis to a rating committee for discussion and requests a vote on final rating assignments. There may be more than one rating committees for a given transaction before a final vote occurs, as additional analysis may be requested by the committee and/or the arranger may choose to alter the transaction prior to closing.

While the final outcome of a rating process appears simple – either a transaction proposal is rejected, or one of 21 discrete ratings[21] is assigned to various tranches of the transaction – the rating process itself can be quite complicated. This is because deal structures and collateral pool compositions can vary from transaction to transaction and model components and parameter choices require careful analysis and deliberations, especially in the world of SF CDOs.

As with all its ratings, Moody's also carefully monitors each SF CDO that it rates.[22] Moody's CDO surveillance team works closely with CDO trustees and collateral managers to ensure that the team has access to the most recent transaction data. In order to determine whether the current rating is still appropriate, surveillance analysts routinely carry out similar analysis, as were performed as of the initial rating date, conditional on the most recent collateral performance data and market conditions.

<u>Simulating Asset Defaults and Losses and Moody's Asset Correlation Analysis</u>

Moody's SF CDO rating models include a set of basic components – default probability, recovery rate, and asset correlation – suited to the assets in the collateral pool. The actual application of the rating model depends on the type of a transaction. For example, the approach to rating transactions with complex and significant payment waterfalls differs somewhat from that for transactions that lack such waterfalls. Additionally, our analysis for managed transactions also differs from the analysis used for static CDOs. We begin with a discussion of our approach that is relevant for synthetic CDOs without complex payment waterfalls and then describe our correlated binomial approach for SF CDOs with complex waterfalls.

For synthetic SF CDOs without significant waterfalls, Moody's employs a Monte Carlo simulation approach that is incorporated in Moody's CDOROM[TM] model. In each Monte Carlo trial, defaults and recovery rates upon default are simulated for each obligation in the reference pool. Losses on each of the CDO tranches are then computed depending on the cumulative losses incurred by the pool for each trial and the attachment and

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[20] Moody's also reviews the capacities and practices of trustees in CDO transactions to better understand their controls and verification procedures.

[21] Moody's uses a rating system that consists of letter ratings (Aaa, Aa, A, Baa, Ba, B, Caa, Ca, C) with a numerical modifier (1, 2, or 3) applied to the rating categories from Aa to Caa. Altogether, there are 21 rating symbols.

[22] See "Moody's Approach: The CDO Monitoring Process," Moody's *Rating Methodology*, September 2002.

detachment points for the tranches. By repeating this process and averaging over a large number of simulations (e.g. 1-3 million), an estimate of the expected loss borne by each tranche is derived. For managed synthetic transactions, the collateral manager typically runs the CDOROM^{TM} model before and after each proposed substitution to determine that the trade will not negatively impact the expected loss for each CDO tranche.[23]

Moody's infers the default probability (DP) of structured assets in a CDO collateral pool based on the rating-EL relationship, in combination with the average life (AL) of an instrument and an assumed recovery rate (RR). The DP for each asset is calculated as EL/(1-RR).

The rating-EL relationship for each structured finance asset is drawn from Moody's idealized expected loss table, which serves as the EL target for each rated structured finance asset.[24] In other words, each structured asset is rated and monitored such that the expected loss for that asset falls within the range of ELs for a specific rating and AL. To the extent that the expected loss for a tranche no longer falls within the EL range for a given rating, the rating is revisited and is upgraded or downgraded accordingly. As such, we use this relationship between the EL and the rating to determine the expected loss assumption for each asset in the reference pool.

The assumed recovery rates, which increase with tranche thickness, the tranche's seniority in the capital structure, and initial rating, and also vary by asset type, are based on Moody's studies of structured finance recovery rates and the expertise of Moody's analysts in each of the asset classes.[25]

The third basic component of the rating model is correlation. Correlation assumptions are a critical component of the CDO rating analysis. Imperfect default correlation of assets is the main reason why a CDO can normally offer tranches with a wide range of risks from Aaa to Caa, regardless of the credit quality of assets.

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[23] See Moody's Special Report, "Managed Synthetic CDOs: Moody's CDOROM^{TM} Guidelines," August 2005.

[24] Moody's idealized loss rates were determined in the late 1980s and were based on Moody's historical corporate default rates by rating and tenor in combination with a historical average recovery rate of 45% for all ratings and tenors. Moody's reported historical corporate default rates using a static method (unadjusted for rating withdrawals) prior to 1996 and has reported the default rates using a dynamic method (adjusted for rating withdrawals) since 1996. The idealized expected loss rate table appears in a number of Moody's Special Comments. For example, see "Default & Loss Rates of Structured Finance Securities: 1993-2006," April 2007. The idealized default rate table for corporate obligations appears in Moody's Special Report, "Moody's Approach to Rating Synthetic CDOs," July 2003. For the latest historical corporate default and recovery rate study, see Moody's Special Comment, "Corporate Default and Recovery Rate, 1920-2006," February 2007. Finally, while structured finance assets and corporate assets share the same idealized expected loss rate table, their default rate and recovery rate assumptions are different. See later sections for more details.

[25] For a detailed discussion of Moody's structured finance default and loss-given-default data, see "Default & Loss Rates of Structured Finance Securities: 1993-2006," Moody's *Special Comment*, April 2007 and "Measuring Loss-Given-Default for Structured Financed Securities: An Update," Moody's *Special Comment*, December 2006. The assumed values of EL associated with each rating level and tenor and the recovery rates for structured assets are contained in Moody's CDOROM™ software.

Moody's current SF CDO rating model does not use specific default correlation assumptions as direct inputs.[26] Instead, it models asset correlation, which captures the co-movement of the asset values that makes joint default more or less likely. With asset correlation, a large number of correlated multivariate normally distributed values are generated from simulations. These simulated values are then compared with the default threshold value of each asset (derived from the asset's default probability), to decide which asset will default – in essence, calculating a default correlation as an intermediate output.[27]

The preference for using asset, rather using default correlations directly, can be summarized as follows:[28]

- Asset correlations are much easier to work with in a simulation framework. More specifically, one can mathematically describe joint events of default in a computationally convenient and widely used way.
- The reliance on asset correlations gives rise to a consistent set of default correlations that can be applied within Moody's traditional BET or another non-simulation framework.
- The asset correlation approach is also quite natural in the structured finance context, where tranche performance clearly depends on the performance of the assets in the collateral pool, which may be correlated across transactions.
- Defaults are rare and binary events. Default correlation is notoriously difficult to measure from the historical data, whereas there is more data available to measure asset correlations.
- Asset correlations exhibit less variation over time even as the credit quality and ratings of individual assets migrate. Default correlations change as credit quality migrates. Under reasonable assumptions, changes in default correlations can be inferred from rating changes themselves if asset correlations are known.

Because asset correlation is extremely important in Moody's SF CDO rating model and there are many other correlation concepts and correlation models in the market, we make the following additional observations.

First, the asset correlation is different from both traditional default correlation and implied correlation from the market price of a tranche. As mentioned above, asset correlation measures the co-movement of asset values in various states, while default correlation measures the correlation of default events between two credits. Implied correlation is typically an output from a model that relies heavily on market prices as inputs. Because implied correlations are based on market prices, they can vary across

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[26] Default correlations were implicit inputs for the Binomial Expansion Technique (BET), which has historically been used by Moody's for the analysis of CLOs and multi-sector CDOs.
[27] This is also known as the Gaussian Copula approach. See Li (2000).
[28] See Moody's Special Report, "Moody's Revisits Its Assumptions Regarding Structured Finance Default (and Asset) Correlations for CDOs," June 2005.

different tranches of the same transaction. The well-known "correlation smile"[29] is an example. More recently, another correlation concept called "base correlation" became popular in the structured credit market. The base correlation is a type of implied correlation and is useful for relative value analysis because it does not vary materially across tranches and has a better correlation skew pattern.[30] We do not use implied correlations in our rating models because they are derived from market prices that can be very volatile and strongly influenced by non-credit risk factors.[31]

Second, Moody's asset correlations within and across various structured finance asset types are inferred from structured finance rating co-movements.[32] Moody's relies on the Directional Ratings Transition Matrix (DRTM) approach to derive a set of asset correlations for structured credits. The choice of the DTRM is largely based on the availability of data and the appropriateness of using rating co-movements to ultimately assess correlations for rating purposes. Rating transitions are available for the major structured finance sectors, are readily accessible, and can be updated frequently.[33] One important extension is the application of the technique to assess correlations between structured and corporate instruments, to which the DRTM is well suited.

Third, because of the limited scope of the data - the fact that we can't derive asset correlations for each pair of narrowly-defined structured finance categories - we must supplement the estimates by imposing a set of assumptions within a well-reasoned scheme. With the inputs from asset-type experts from each of the structured finance rating groups, Moody's developed a set of increasingly refined sector definitions, within which we would expect the performance of the underlying assets to be increasingly linked.

To be more precise, Moody's first defines a set of "meta" categories such as a consumer sector and a corporate sector within which there is a modest degree of linkage of the underlying assets. Beneath each of the meta sectors, there are broad sectors such as consumer ABS, RMBS, and CMBS within which the underlying assets may be more tightly linked. Each broad sector is comprised of a set of narrow sectors such as auto, credit card, and subprime RMBS.

Moody's recognizes that, for structured finance obligations, factors other than sector may come into play in the determination of asset correlations. These additional factors include

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[29] The "correlation smile" describes an empirical observation that the implied correlations based on a Gaussian Copula model and market prices are higher for both first-loss and senior tranches but lower on mezzanine tranches.

[30] See Morgan Stanley, "Structured Credit Insights: Instruments, Valuation, and Strategies," Second Edition, April 2006. Hull and While (2006) proposed an alternative to the Gaussian Copula/base correlation approach. Instead of implying copula correlations from market prices they imply the copula itself.

[31] Moody's always tracks the cutting-edge CDO market research and remains committed to revisiting its rating models and making changes if necessary.

[32] Moody's discussed the rationale of this approach to determining asset correlations in a Special Report, "Moody's Revisits Its Assumptions Regarding Structured Finance Default (and Asset) Correlations for CDOs," June 2005.

[33] Moody's publishes annual structured finance rating transition studies. For the latest report, please see Moody's Special Comment, "Structured Finance Rating Transitions: 1983-2006," February 2007.

region (e.g. U.S. vs. European RMBS), vintage (e.g. deals issued in 2006 vs. deals issued in 2002), and key agent (e.g. originator, servicer, collateral manager).[34] To the extent that assets share these additional common traits, higher asset correlations are applied.

Finally, in determining the asset correlation parameters for our models, we incorporated additional stresses to take into account the significant standard error that could arise around some correlation estimates. Along with all of our modeling assumptions, we continue to re-assess our correlation estimates as new data is generated and as market conditions evolve. We understand that correlation modeling continues to be an important research topic among credit professionals and we strive to stay at the forefront of this research and incorporate future findings into our rating models.

<u>Moody's Correlated Binomial Model for Cash Flow and Hybrid SF CDOs</u>

For cash flow and hybrid SF CDOs that have complex waterfalls, a full version of the Monte Carlo simulation model is not practical because of its long computation time and the managed nature of most of these transactions. Meanwhile, the fat-tailed loss distribution of recent-vintage structured finance collateral due to high correlation and low diversity makes it difficult to employ Moody's traditional Binomial Expansion Technology (BET) approach that relies on Diversity Score (DS).[35] Consequently, Moody's developed a correlated binomial model (CBM) to rate these types of SF CDOs. The model provides analytic consistency in rating cash flow and synthetic CDOs, model specification parsimony, and transaction manageability.[36]

Moody's CBM approach has four parameters – common default probability, common recovery rate, number of representative assets, and Moody's Asset Correlation (MAC). For those that are familiar with the older BET methodology that was used for earlier vintage SF CDOs, the first two parameters are the same while the second two are specific to the CBM methodology.

Within the CBM, Moody's infers the default probability of the CDO collateral from the weighted average rating of the assets and assumed average recovery rate. For this purpose, each alpha-numeric rating is associated with a particular "rating factor."[37] For structured

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[34] For a study on the role of deal sponsor in the credit performance of ABS and MBS securities, please see Moody's Special Comment, "Deal Sponsor and Credit Risk of U.S. ABS and MBS Securities," November 2006.

[35] The BET approach maps the portfolio of assets into a hypothetical portfolio of N number of uncorrelated, homogeneous assets with identical default probabilities and equal par values. The number N is the Diversity Score. The higher the DS, the more diversified the portfolio. The BET approach calculates expected losses from defaults in the hypothetical portfolio, going from zero defaults to N defaults and assigning a probability to each default scenario. See Moody's Special Report, "The Binomial Expansion Method Applied to CBO/CLO Analysis," December 1996.

[36] For details of Moody's CBM approach, please see Moody's Special Report, "Moody's Modeling Approach to Rating Structured Finance Cash Flow CDO Transactions," September 2005, and "Moody's Correlated Binomial Default Distribution," Moody's Rating Methodology, August 2004.

[37] Moody's rating factor is a numeric metric assigned to each rating level reflecting the expected defaults for the rating category. Moody's weighted average rating factor (WARF) is the average of these numeric

assets, the rating factor, in combination with the average life of an instrument, is associated with a particular EL. Hence the weighted average rating factor (or "WARF") of the pool, in conjunction with the weighted average life ("WAL") of the collateral, determines the EL of the collateral assets.

Because EL is the product of the probability of default and the loss given default ("LGD"), and since the LGD is just one minus the recovery rate, it is possible to infer a pool-wide average default probability from: 1) the WARF, 2) the WAL and 3) the weighted average recovery rate ("WARR").

Moody's Asset Correlation (MAC) in the rating of cash SF CDOs comes from the same correlation model developed for synthetic transactions. The MAC represents the average asset correlation among a fixed number of representative (with identical ratings) assets in a model portfolio and is based on the asset correlations among the actual portfolio assets. In the traditional BET, the Diversity Score reflects the number of representative (also with identical ratings) assets assuming 0% correlation (full independence) among the assets in the model portfolio. In the CBM, we fix the number of representative assets in the model portfolio and calculate the correlations among those assets. Moody's CDOROM^{TM} model calculates the MAC value by simulating many different loss scenarios for the portfolio, then identifying the CBM parameters that best match the first and third moment of the simulated loss distribution with those of the model portfolio.

Moody's also considers both expected and stressed WAL scenarios to take into account the fact that the tenor of mortgage-backed instruments may vary substantially with prepayment speeds. Various interest rate stresses are also applied. In addition, the timing of defaults is assumed to depend on the types of assets included in the collateral pool. Moody's normally considers a range of possible default timings. Together, the CBM considers thirty interest rate and default timing scenarios for each of three prepayment speed scenarios.

Like the BET, the CBM generates a probability for each possible default scenario and then each default scenario is run through the waterfall structure. The EL for each tranche, weighted over the 90 scenarios described above[38], is calculated and compared with a set of EL hurdles by rating and tenor in order to determine a rating, i.e. if the calculated EL is less than the EL hurdle, the targeted rating of the tranche is considered to have passed the hurdle; otherwise the target rating fails.

As discussed earlier, the rating committee often requests that additional stresses and scenarios are presented before a final rating decision is made. These additional modeling runs may be requested to address a particular concern for a specific transaction or to address any current and foreseeable changes in market conditions that may arise over the course of the analysis.

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values across the collateral pool, weighted by the balance of the assets in the pool. The higher the WARF the more defaults are expected in the collateral pool.

[38] A weight of 50%, 25%, and 25% is applied to each of the following three scenarios: base, slow, and fast amortization profiles, respectively.

For example, given the high ratings volatility currently associated with the 2005 and 2006 vintage subprime RMBS transactions and the higher correlations in the market today, Moody's rating committees have been requiring modeling scenarios that stress both the default probability and correlation parameters.

Structural Features in SF CDOs

For rating SF CDOs, Moody's requests par haircuts in the calculation of over-collateralization (O/C) ratios for certain assets that carry non-investment grade ratings.[39] Moody's assigns a 90% par credit (or a 10% haircut) to Ba-rated structured assets, an 80% par credit to single-B assets, and a 50% par credit to Caa-rated assets. The haircuts protect the noteholders by causing the O/C tests to be triggered when there is deterioration in the collateral pool and by diverting excess spread to pay down the notes sequentially.

Moody's has also been concerned with collateral debt securities that are purchased at deep discounts, mainly because of the collateral manager's incentive to prop up the par value for O/C compliance and to adversely select assets that generate higher returns for a given average rating. For structured finance assets rated single-A or below, Moody's assigns a par credit that is the lesser of purchase price and rating-based par credit if the initial purchase price is less than 0.75 of the face value, and the lesser of 100% and rating-based par credit if the initial purchase price is greater than 0.75. For floating-rate structured assets rated Aaa and Aa, if the initial purchase price is less than 0.92, the par credit is the purchase price; otherwise, the par credit is 100%.[40]

O/C haircuts are not the only area where discount purchase haircuts have been applied. We have used market value information actively in rating synthetic transactions and for synthetic reference obligations in deals with full capital structures.[41] Moody's rating committees have been requesting scenarios stresses to modeled enhancement levels and/or default probabilities for structured finance collateral trading at deep discounts or wide CDS spreads.

Finally, in order to capture the trend of rating migration and therefore more accurately reflect the credit quality of structured finance assets, Moody's has also historically assumed the rating on a security that is on downgrade-review to be a few notches below

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[39] Moody's generally applies haircuts for excess Caa assets and deep discount obligations for all assets. The use of par haircuts may be more important in SF CDOs than CDOs backed by corporate assets because the timing of default for structured assets may differ substantially from that of corporate bonds and loans.
[40] See Moody's Structured Finance Rating Methodology, "CDO RatingFactors vol. II…No.5: Par Haircuts in Structured Finance CDOs," January 2006.
[41] CDO collateral managers are required to determine the market value of collateral from objective sources as defined by the CDO indenture. The key objective source has been bid-side quotes from more than one independent nationally recognized dealer who actively trades that security. Typically, CDOs use the average of three such quotes or the lower of two if three are not available. See Moody's Structured Finance Rating Methodology, "CDO RatingFactors vol. II…No.4: Assigning Market Value to CDO Assets," December 2005.

the current rating. Conversely, a rating that is on upgrade-review is also assumed to be a couple of notches above the current rating. These assumptions take into account historical data that shows that ratings that are on review are highly likely to move in the direction of the review. Also, when the upgrade or downgrade action is taken, it is likely to be on the order of a few notches.[42]

4. Credit Performance of SF CDOs

Evaluating the credit performance of CDOs is somewhat challenging as the performance may be strongly influenced by the credit cycle of the underlying assets and the distribution of asset types, which are constantly changing over time. Some CDO deal types and asset collateral quickly exited the CDO sector after they were severely impacted by negative credit cycles. One notable example is HY CBOs, which was the leading CDO category before 2002. This CDO category almost became extinct in 2002 as the last recession caused a huge spike in the default rates of high yield corporate bonds.

Another example is multi-sector CDOs backed partially by manufactured housing loan, aircraft lease, and franchise loan ABS issued during 2000-2002. These three ABS categories experienced high downgrade rates and impairment rates because of the negative impact from the same recession that was further spread into the consumer, airline, and small business sectors. As a result, MH ABS, aircraft lease, and franchise loan ABS disappeared as a material CDO collateral type after 2002.

The migration of asset collateral types over time within the SF CDO sector resulted in an unbalanced data sample with data observations covering less than a full credit cycle for major CDO deal types. Interpreting the average statistics for the entire sector over such a short data sample period becomes challenging. In this section, we focus on a few lifetime performance statistics for SF CDOs.[43] Figure 6 provides the count of lifetime downgrades, upgrades, and unchanged ratings on SF CDOs issued prior to 2006. Note that it is customary to leave out the latest vintage in our measure of lifetime performance statistics to avoid data sample biases due to the lack of seasoning. That said, we realize that once the full impact of ratings migration and impairments for the 2006 vintage are accounted for, we expect to see very different results for this vintage compared to the earlier vintages SF CDOs.

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[42] Moody's first documented the strong rating change momentum effects in structured finance in a Special Comment, "Structured Finance Rating Transitions: 1983-2002, Comparisons with Corporate Ratings and Across Sectors" January 2003, and studied the resolution of watchlist actions in structured finance in a Special Comment, "Structured Finance Watchlist Resolutions: 1992-2003," June 2004.
[43] Moody's publishes credit performance research reports for structured finance securities on a regular basis. On an annual basis, Moody's reports global structured finance rating transition, default, loss-given-default, and realized loss rate statistics. For the latest rating transition study, please see "Structured Finance Rating Transitions: 1983-2006," February 2007, and for the latest default and loss-given-default study, please see "Default & Loss Rates of Structured Finance Securities: 1993-2006," April 2007. Moody's also publishes structured finance rating performance metrics reports on a semi-annual basis. For the latest, please see "The Performance of Structured Finance Ratings: Full-Year 2006 Report," May 2007.

As the Figure shows, the overwhelming majority of the SF CDO securities issued during 1999-2005 did not experience rating changes. Aaa-rated securities displayed the lowest downgrade rate of roughly 6%, compared to the 15-16% downgrade rates for securities rated Baa or below.

Figure 6 –

Number of Downgraded, Upgraded and Unchanged Ratings on SF CDOs Issued During 1999-2005
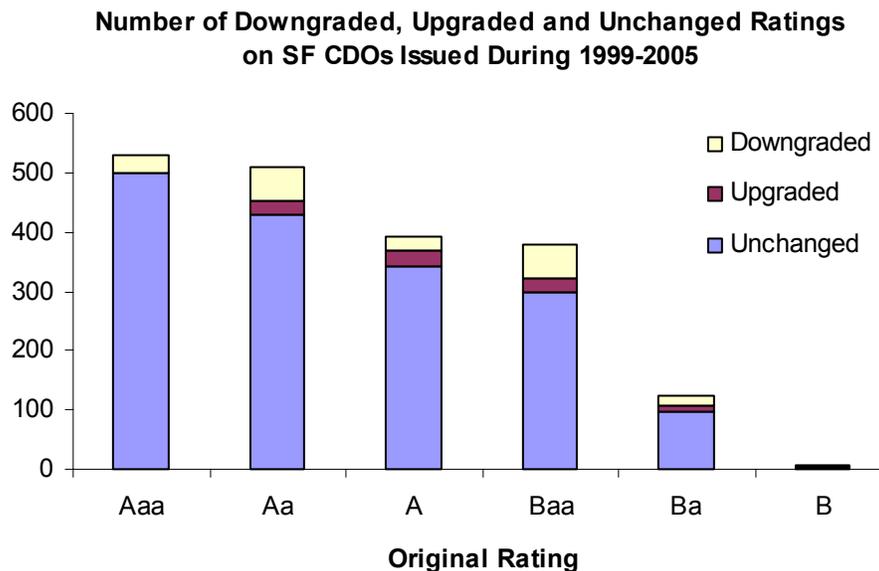
Note: The rating transition experiences of these securities are updated through the end of April 2007.

Aside from rating transitions, another important measure of credit performance is the incidence of default. Moody's employs a material impairment concept in its study of structured finance ratings performance. Structured finance instruments are defined as "materially impaired" if they have suffered an interest shortfall or principal write-down that remained uncured at the end of a study period. Securities downgraded to Ca or C even though they have not sustained any interest or principal losses are also called "materially impaired". Furthermore, Moody's defines structured securities that have suffered principal loss or downgraded to Ca or C as being "principal impaired."[44]

Figure 7 reports the total SF CDO issuance in billions of US dollars and the lifetime impairment (principal impairment) rate by securities' original ratings. Two observations are noteworthy.

First, more than US$150 billion Aaa-rated SF CDO tranches issued prior to 2006 did not suffer any material impairments as of the end of 2006. For about US$24 billion of Aa tranches in the SF CDO sector, the lifetime impairment rate is approximately 30 basis points of their original balance. The lifetime impairment rate of Baa tranches appears higher at about 9%, which stemmed from the poor performance of the early vintage

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[44] See Moody's Special Comment, "Default & Loss Rates of Structured Finance Securities: 1993-2006," April 2007.

multi-sector SF CDOs backed by ABS of manufactured housing loans, aircraft leases, franchise loans, and high yield CBOs.

Second, original ratings have in general provided a good rank-ordering of the lifetime impairment rates, i.e. the impairment rates were higher in lower rating categories. The only exception is observed between the Baa and Ba categories. This is the result of a data sample bias. Many SF CDO transactions did not carry Ba ratings, either because there are no such tranches offered in the deal, or because Moody's was not asked to rate these tranches for various reasons. In fact, over the period of 1999-2005, Moody's assigned 436 Baa ratings, but just 124 Ba ratings (including pari passu tranches). If all deals carrying Baa-rated tranches also included Ba-rated tranches, the rank-ordering of the impairment rates would be strictly monotonic.

Figure 7 -
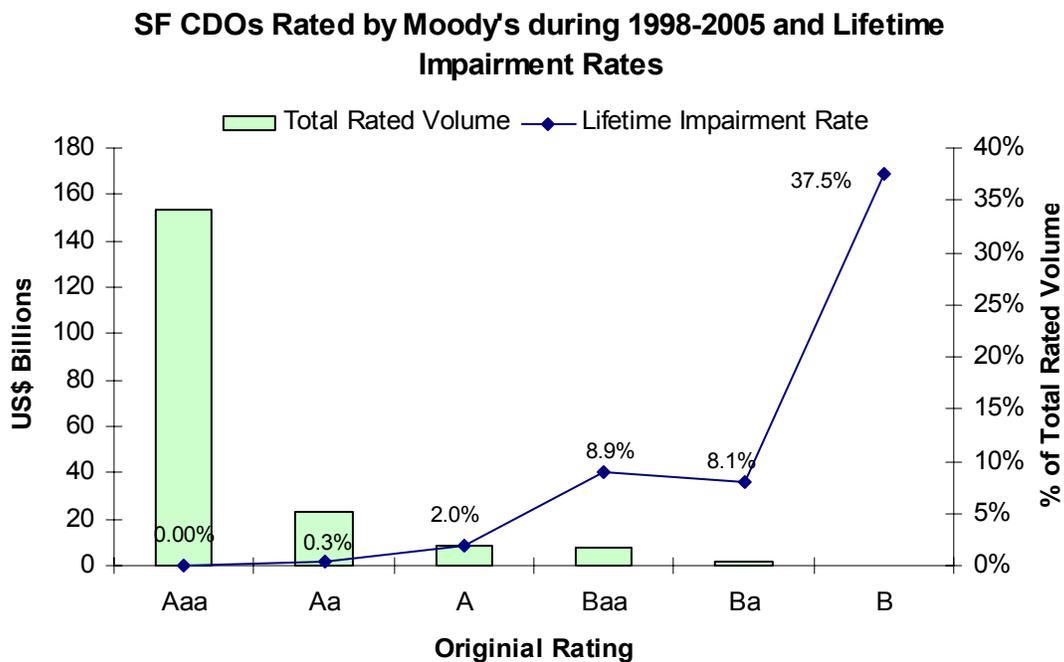
Note: Non-US dollar denominated and wrapped tranches are not included. Data are as of the end of 2006. The lifetime impairment rate is the total original balance of impaired securities divided by the total original balance of all securities within a rating bucket.

Figure 8 plots the distribution of SF CDO impairments as of the end of 2006.[45] The first chart of Figure 8 shows that 33, or 60%, of the 54 SF CDO impairments were initially rated Baa. Single-A and Ba-rated impairments accounted for 15% and 17% each.

The second chart of Figure 8 depicts the concentration of impairments in three vintages – the tranches issued in 2000, 2001, and 2002 contributed 90% of all SF CDO impairments

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[45] Tranches issued in 2006 are not included. As we will discuss later, these tranches are expected to perform poorly.

to date. More notably, tranches issued during 2003-2005 had not experienced any impairments as of the end of 2006.

Figure 8 – Number and Share of Impaired SF CDOs (Total 54 Tranches as of the End of 2006) by Original Rating (first chart) and Year of Issuance (second chart)
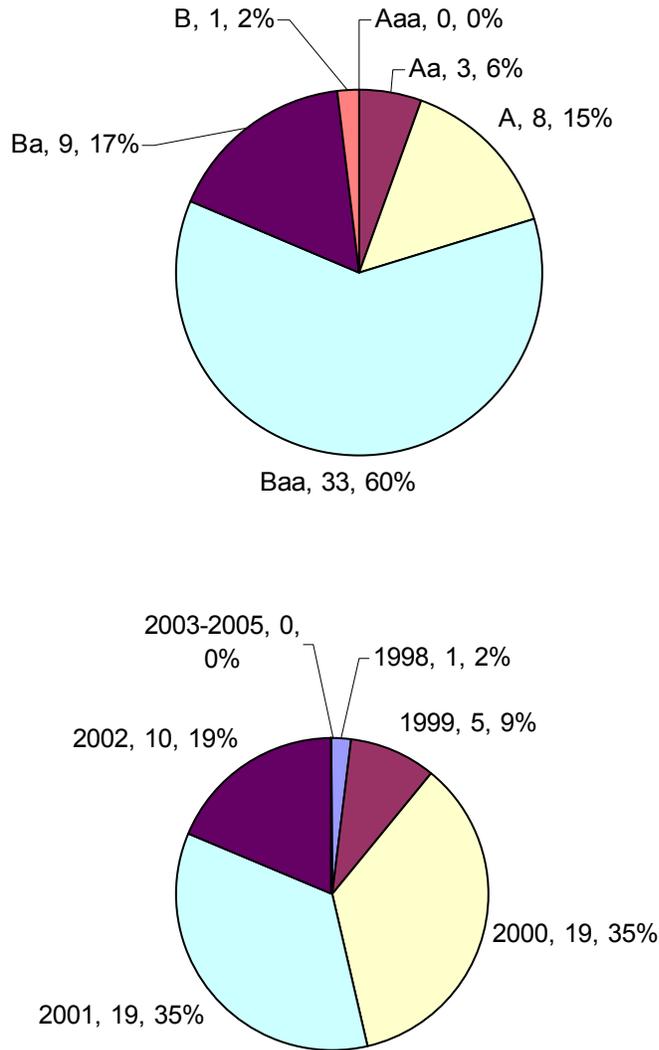
In Figure 7 and Figure 8, we excluded the SF CDO securities issued in 2006. The main reason is that for the lifetime performance statistics, it generally does not make sense to include the latest vintage data due to their lack of seasoning. Even with the recent swift rise in delinquencies of the mortgages underlying the RMBS transactions, there has not been any impairment or loss as yet among SF CDOs issued in 2006 although some are expected to suffer losses in the future.

For example, on July 10 this year Moody's announced negative rating actions on 431 securities originated in 2006 and backed by subprime first lien mortgage loans. Of the 431 rating actions, Moody's downgraded 399 securities and placed an additional 32 securities on review for possible downgrade. The negative rating actions affected securities with an original face value of over $5.2 billion, representing 1.2% of the dollar volume and 6.8% of the securities rated by Moody's in 2006 that were backed by subprime first lien loans.[46]

On the following day, Moody's announced that it had put 184 tranches of 91 collateralized debt obligations (CDOs) backed primarily by residential mortgage-backed securities (RMBS) on review for possible downgrade. The rating actions affected securities with an original face value of approximately $5.0 billion, representing roughly 0.5% of the total Moody's rated asset backed security CDO (SF CDO) universe. These CDO rating actions primarily reflected the July rating actions on RMBS assets associated with first lien subprime mortgages from the 2006 vintage and earlier rating actions on RMBS backed by second lien loans of the 2005/2006 vintage. The majority of rating actions taken (124 rating actions) impacted securities rated Baa or lower.[47]

Since then, Moody's has taken more rating actions on both 1st lien and 2nd lien RMBS transactions. As a result, more SF CDO tranches have been placed on review and downgrades of SF CDO ratings previously placed on review have begun to filter through. Given the scope and magnitude of these downgrades and continuing distress in the subprime RMBS sector, we expect a significant portion of the SF CDO securities issued in 2006 to eventually perform worse than those analyzed in Figures 7 and 8.[48] Based on a hypothetical cash flow CDO, Moody's studied various combinations of assumed subprime RMBS downgrades and defaults, some of which were quite severe. We found that the effects were generally moderate for SF CDOs with exposure to subprime RMBS up to the observed average, but could be severe for the most heavily exposed transactions.[49]

While the 2006-vintage SF CDOs in general are expected to underperform, it is worth stressing that the performance of CDOs tends to vary substantially across transactions even within a deal type and the asset collateral across different deal types are subject to different credit cycles. The loss of data observations from the better part of a credit cycle often results in severe data censoring. The rating performance of CDOs cannot be evaluated properly unless we have an "average" credit environment covering at least one full credit cycle for the underlying CDO assets.

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[46] See Moody's rating action press release, "Moody's Downgrades Subprime First-Lien RMBS," July 10, 2007.
[47] See Moody's rating action press release, "Moody's Puts 184 CDO Tranches on Review for Possible Downgrade," July 11, 2007
[48] For a preliminary analysis of the impact of subprime RMBS performance on SF CDOs, please see Moody's Special Report, "The Impact of Subprime Residential Mortgage-Backed Securities on Moody's Rated Structured Finance CDOs: A Preliminary Review," March 23, 2007.
[49] See Moody's Special Report, "The Impact of Subprime Residential Mortgage-Backed Securities on Moody's-Rated Structured Finance CDOs: A Preliminary Review," March 23, 2007.

To give an example, HY CLOs are one of a few CDO deal types that have lived through one full credit cycle and have a sufficiently large number of data observations. CLOs entered the CDO market around the same time as HY CBOs in late 1990s and are still popular today. As Moody's discussed in several credit performance reports for structured finance securities, CLOs has been one of the best performing structured finance asset classes. We note, however, even in this sector there have been changes to the underlying loans and the structures of the CLOs themselves.

Another notable observation in the evaluation of the credit performance of CDOs is the correlation effect from the overlapping of the underlying assets across transactions. In fact, it is quite common for different CDOs to source or reference some of the same set of credits.[50] Such correlation effect makes the CDO performance worse than indicated by the performance of the underlying asset classes – one downgrade or default in the asset collateral may lead to the downgrades of many CDOs that are backed or reference the same credit. For example, Moody's noted that in 2005, 48 or about 88% of the 56 downgrades in the year were related to the default of Delphi, an automobile part maker.[51]

The study of CDO ratings performance is further complicated by the truncation of rating observations in the sense that Moody's does not always assign ratings to all tranches of a given deal, and in some cases, a deal has just one single tranche (single-tranche synthetic CDOs are also known as bespoke tranches.)

5. **Concluding Remarks and Future Research**

This paper described the evolution of the SF CDO market, Moody's analytical approaches to the rating of SF CDOs and their credit performance. We showed that the SF CDO sector has experienced significant changes over the past eight years not only with respect to the distribution of asset collateral and deal structures, but also with respect to the modeling of different components of the rating model and the credit performance of CDO tranches.

We also showed that Moody's SF CDO rating approach involves both quantitative and qualitative assessments and balances model precision, analytical tractability, and data availability. We discussed different approaches to modeling correlations and illustrated why and how Moody's developed a set of asset correlation assumptions for the rating of SF CDOs. We analyzed differences and similarities across different rating models for transactions with and without complex waterfalls. Finally, we stressed the unique data sampling issues in the evaluation of credit performance for the SF CDO sector and highlighted some historical performance patterns in the sector.

As the CDO market continues to learn from its past and introduces new asset collateral and new structural design, rating analysts inevitably will face greater challenges both

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[50] Note that this is yet another type of correlation, which describes the relationship not within a particular CDO but across CDOs. This correlation is particularly important for CDOs of CDOs, or CDO-square.
[51] See Moody's Special Comment, "European Structured Finance Rating Transitions: 1988-2005," February 2006.

quantitatively and qualitatively and will continue to fine tune their existing rating models and to develop new approaches.

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